ELECTRICAL RATES: THE LOAD FACTOR AND THE DENSITY FACTOR

SUMMARY

Scope of this paper, 519. — I. The load factor important in electricity because of a peculiar technical situation, 521. — Relates especially to fixed charges, 523.—Load curves, 525.—Diversity as important as long hours' use, 527. — Explicit load-factor rates, 529. — Adequate metering practicable for large consumers, 531. — The load factor an instrument of price-differentiation; its application a matter of commercial policy, 532. — II. Quantity discounts in practice especially difficult to deal with, 533. — The grounds of especially low rates to large consumers; such rates tend to be discriminatory, 534. — Step and block rates, 536. — Effects of isolated-plant competition, 538. — Proposed density factor discounts, 539. — Differentiation thus instead of discrimination, 540.—III. Cost analysis only one among several elements in electrical rate-making, 540. — Differential policy in load-factor rates, 541. — Wholesale discounts, also, are actually differential, 544.

A COMPREHENSIVE study of electrical rates would require one to pass in review the various features of electrical rate schedules. The variety and complexity of devices adopted by electrical companies to fit the charge to the special circumstances of the consumer, including the time when the service is rendered to him, are not exceeded in any branch of industry. There is no room for description of such devices in this paper. Even some of the more fundamental points of electrical rate theory and practice must be disposed of with bare mention. The present paper deals mainly with two fundamental questions: (1) the bearing of the time of consumption upon the rate, and (2) the proper influence of quantity taken upon the rate.

Consumer cost, however, is an element so important in the charge the electrical company makes to the small consumer, that it should be mentioned in passing. It consists of the cost of keeping separate accounts and rendering and collecting bills individually, of reading and maintaining the meter, of the carrying charges upon meter and meter installation; often also of carrying charges and maintenance for the service connecting the consumer's premises with the circuit in the street. All vary per consumer rather than per kilowatt hour; the amount, in other words, is nearly constant for the ordinary consumer whether he uses much or little electricity. This may be a separate element in the rate, that is, a consumer charge may take the place in part of what would otherwise be a higher kilowatt-hour charge; or it may be taken account of through mere "classification," that is, the putting of small consumers into a high rate (per kilowatt hour) class. But the present paper does not attempt to deal with this aspect of electrical rates.

With the necessary or standard average cost of electricity per kilowatt hour, or how this average is constituted, also, this paper is not concerned. Some costs do not lend themselves to allocation per kilowatt hour, and are not connected with the load factor question presently to be considered. And further, as to the costs that are variable and separable per kilowatt hour — supposing for the moment that the question relating to the average cost can be thus subdivided and limited — no analysis of the average and no attempt to determine its significance, or the share of total cost which the kilowatt-hour charge should take care of, is here made.

I. Load-Factor Rates

The importance of the load factor constitutes the special peculiarity of electrical rates. It is sufficient for present purposes to define the term as the ratio of average to maximum load.[1] By load is meant the kilowatts carried by a power station or generator or other machine, or the kilowatts required by a consumer or group of consumers.

Kilowatts, tho primarily a measure of capacity, in this connection serve to measure the rate of output, *i.e.*, of the consumption of energy. The rate of output at a given time corresponds to the utilized capacity, or the load, at that time. A rate of output of one kilowatt kept up during one hour gives a quantity of output of one kilowatt hour. So if we wish to arrive at the *average* output (or average load) of some specified power station for a year we divide the kilowatt-hour output for the year by 8760, the number of hours in the year; which gives us one term of the load-factor ratio.

The other term is the *highest* recorded output for some brief interval — five minutes, fifteen minutes, or half an hour, or possibly longer. Sometimes the instantaneous maximum has been used, but the American Institute of Electrical Engineers disapproves of this, doubtless because the capacity of a generator for a brief interval is much greater than its continuous rating, so that the technical and economic significance of a load factor based upon an instantaneous maximum, probably the result of a brief fluctuation of the load, is less than where the load for some appreciable interval

[1] The definition of the Standardization Rules of the American Institute of Electrical Engineers is as follows: " The ratio of the average power to the maximum power during a certain period of time. The average power is taken over a certain period of time, such as a day, a month, or a year, and the maximum is taken as the average over a short interval of the maximum load within that period."

is taken. It should perhaps be noted that the latter sort of maximum load is strictly the average kilowatts for the interval in question, tho of course measured integrally instead of being derived by an arithmetical operation upon a series of measurements.

It should be noted that the load factor is essentially an economic rather than a technological matter. The output of an electrical company is obviously determined by the needs and wishes of its consumers. Its maximum output is also determined by its consumers. It is the business of the company to be ready with the supply when it is wanted. If an electrical company seeks to increase its load factor, it must operate through the motives and habits of actual and possible consumers, in other words, not through internal organization and management, but through selling policies and rate schedules.

Until recently, and even now to some extent, the load factor has frequently been confused with the capacity factor. This is the ratio of average output to *capacity;* a technological matter, mentioned here chiefly to emphasize by way of contrast the economic character of the load factor proper. A plant with a capacity of 50,000 kilowatts may have maximum loads in successive years of 40,000, 45,000, and 50,000 kilowatts, or even something more. The fact that plants are planned to provide for future growth, and the fact that the most economical generator unit tends to be very large — 30,000 kilowatts is coming to be familiar — give the capacity factor a significance of its own. But it may sometimes be used as a makeshift in place of the load factor, economically more significant. This is in effect what happens when the capacity of a consumer's installation is employed, instead of his actual maximum demand, to determine the amount of his bill under a load-factor rate.

The peculiar technical situation in relation to electrical supply gives the load factor outstanding and peculiar importance there.[1] In manufactures, goods are made in anticipation of need, and are stored until consumers are ready and an economic demand for the goods results. In the gas industry storage is possible, tho the capacity of gas holders is seldom more than one day's supply. In electricity supply storage is not yet economically practicable. The energy must be generated at the moment of demand. Accordingly grates and boilers must be designed so that the quantity of water vaporized can be doubled on a moment's notice, and the generators must be able to take care of rapid changes in the load.

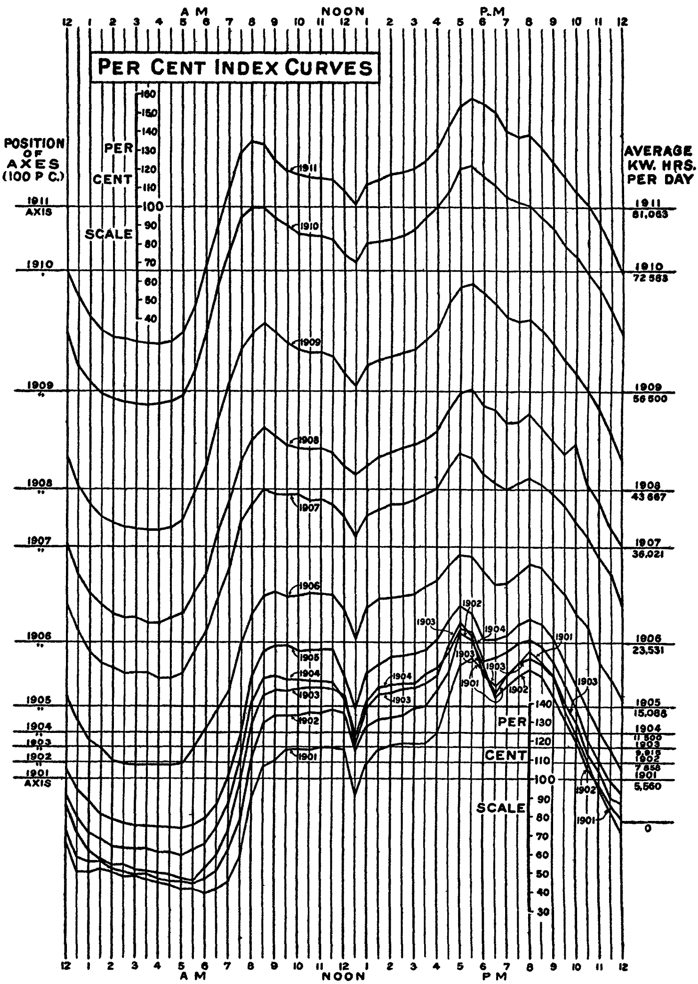
But the operating problems occasioned by the peak load are of comparatively small general bearing. If engineers and managers were not able to meet them they could not retain the business. So far as sharp and sudden peaks increase operating costs, they should of course be recovered, if possible, in the rates charged to consumers responsible for such costs. The more fundamental aspect of the importance of the load factor to the electrical company is the necessity of providing a plant sufficient to meet maximum demand. Most of the time the capacity of the plant is utilized only to a small extent.

Electricity supply doubtless ranks very high among the branches of industry as regards the weight of fixed charges in total costs. If we take rate of obsolescence of appliances into account, the comparative importance of the fixed-charge element in cost becomes relatively still higher. Hence, according to whether the plant is

[1] The nature and significance of the load factor should not be difficult to grasp, but it happens not to be familiar to the student of economics In an article in the American Economic Review for December, 1915, the writer has tried to show that the conception is of greater or less importance in nearly all fields of economic study.

AVERAGE 24-HOUR VARIATION OF THE LOAD, 1901-1911

COMMONWEALTH EDISON CO. OF CHICAGO



much or little used, the fixed-charge element in cost, which can never be unimportant in total cost, will be relatively less or greater, respectively, as an element in the cost per unit of service. But the degree of economically possible utilization of the plant is measured by the load factor. If the load factor can be increased from 15 per cent to 30 per cent, the company can afford to take from the consumer of a given amount of electricity only half the contribution to meet fixed charges it formerly required.

Load curves best illustrate the actual character of the variation of the load. The accompanying full-page diagram shows the average daily variation of the load of the Commonwealth Edison Company of Chicago for a series of years, that is from 1901 to 1911 inclusive, in the form of per cent index curves.[1] The data represent

[1] The special use of the per cent index plan calls for brief explanation. It is chosen as the best means of showing comparative variation of electrical loads. In preparation for plotting, the figure for the average load for the 24-hour period is divided into each of the half-hourly values in the series of data for the particular year. The quotients (per cents) thus obtained are plotted above and below a mean axis, which represents unity or the average (the divisor) The value of a unit of the scale is therefore different for each curve and the curves do not show kilowatts The emphasis is upon relative (per cent) variation from the average instead of upon absolute changes

The curves are merely a special type of arithmetical curve, being referred to a 100 per cent axis, regardless of the absolute value of the series, instead of to a zero base. Each curve varies above and below its own axis. Ordinary arithmetical curves, if more than two or three in number and representing magnitudes at all diversified, cannot be compared to advantage with reference to their relative variation. The relative range of variation — of which the load factor is a function — is what is significant in the above curves. The eye can readily grasp resemblances and differences in this respect, as it cannot when all these curves are drawn to the same arithmetical scale. If the reader is interested in statistical graphics, he should compare the above diagram with the same facts represented by curves drawn to a single ordinary arithmetical scale in the "Report of the Committee on Gas, Oil and Electric Light (Chicago City Council) on the Investigation of the Commonwealth Edison Co.," May, 1913, p 22. There the relative variations are distorted and made difficult or impossible of comparison

These curves possess in large degree the property that is the special advantage of logarithmic curves in that they express relativity But they are at the same time more readily understood by the layman who has not enough use for the latter to furnish him with the necessary incentive to learn what they mean. It is important to note that in the per cent index curves the relativity in question applies as between the various curves, but not as between parts (equal intercepts on the ordinates) at different heights of the same curve. In other words, the 10 points between 120 and 130 per cent are not relatively of the same significance as the 10 points between 80 and 90. In a logarithmic curve, on the other hand, there is true relativity as between its parts, so that,

the daily variation unaffected by differences of season or day of week; since for each year, to give the values shown, averages for every successive eighth day for the kilowatts at each half hour were obtained.

The special character of the curve used — the per cent index curve — makes it possible to locate the axes for the various years and thus to facilitate comparison between the years. The axes are accordingly arranged on an arithmetic scale which shows the growth of the business of the company from an average output of 5,560 to 81,063 kilowatt hours (approximately) per day in a period of ten years. Mr. Insull, the president of the Commonwealth Edison Company, is well known as an advocate of centralization of electricity supply and he practises successfully what he preaches. The curves show a lessened variation of the load between 1901 and 1911, in other words, an improvement of the load factor, but not a very marked change. As computed for the average condition shown, the diurnal load factor was 59.8 per cent in 1901 and 63.3 per cent in 1911. Meanwhile the annual load factor was raised from 29.3 to 43.5 per cent. The change in the time of the peak is perhaps of more general significance. In

for example, the graphic value of the 10 points between 80 and 90 is equal to that of the 15 points between 120 and 135 But the constancy of the representation of equivalent kilowatts for the parts of the same curve is probably an advantage of the per cent index curve used as it is in the diagram

If one were to attempt to draw in the zero bases for the per cent index curves in the diagram, the result would be merely confusing To omit the base would be very bad graphic practice for ordinary arithmetical curves, because in such a case the area between the curve and the base line is primarily significant and the course of the curve is significant only because it shows the development and variation of that area So far as the same principle applies to these per cent index curves, it is the variation of the area between the curve and the axis that is significant But where the zero base is equidistant from each of the axes of reference, the effect is much like that for logarithmic curves In the latter case the zero base is infinitely distant so that the position of the curves in relation to each other can be shifted vertically at will with a view to better comparison

The data for the diagram were obtained by Mr L H Lubarsky from the Commonwealth Edison Co for use in a book on statistical graphics that he is preparing To him, also, the writer is indebted for the construction, according to plans jointly made, of the diagram and figures used in this paper

1901 it came at 8 P.M.;[1] in 1911 at 5.30 P.M. In view of the fact that these data are year-round averages, it would appear that the overlapping of lighting for commercial purposes upon power uses during the comparatively few short days must result in a peak much more pronounced than appears in the average values plotted. The evening lighting load should show a nearly constant maximum the year round. The kind of lighting that constituted the peak at the earlier date is now nearly all off-peak, even on the showing of the curves as they stand; and, for the reason just mentioned, at the actual peak season in winter the diversity of this class of business would doubtless appear more marked.[2] In but few cities, it is true, would this situation be so highly developed or advanced as in Chicago. But the central stations are everywhere striving to diversify their business and especially to get large power consumers. In most large cities, therefore, if it is not already true that domestic lighting is mainly off the peak, it is likely that it will be so before long.

From the discussion of this diagram there is a natural transition to the consideration of the diversity factor. Disregarding certain refinements of the formal definition [3] that have no direct relation to present questions, we may describe the diversity factor as the ratio of the sum of the maxima of a group of consumers to the

[1] The curves are somewhat confusingly mixed at the lower part of the diagram — a defect from the point of view of graphics. But this is preferred either to sacrificing the disposition of the axes along an arithmetical scale or to reducing the range of variation indicated by a given per cent.

[2] Cf. the New York Edison curve for December, 1911, in the diagram opposite page 72 of vol. iii of the Report of the New York Public Service Commission for the First District for 1913. The same company's 1913 curve is much improved by its having meanwhile taken on the Third Avenue street railway system.

[3] The definition of the Standardization Rules of the American Institute of Electrical Engineers is as follows: "The ratio of the sum of the maximum power demands of the subdivisions of any system or parts of a system to the maximum demand of the whole system or of the part of the system under consideration, measured at the point of supply."

maximum demand of the group in question when the individual requirements are combined. This ratio is greater than unity, often much greater. A certain much-used figure of the diversity factor for residence lighting from consumers to power station shows 5.5 or 550 per cent. Of course the diversity factor applies between groups as well as between individuals.

What the diversity factor signifies is that the bad load factor of an industry, of a particular kind of business, or of an individual consumer, does not determine whether the business is comparatively unprofitable to the central station, because the maximum may come at a different time from the general central-station maximum and most of the consumption may be off-peak, in which case the company's load factor can only be improved by the accession of the business in question. A commercial bank does not object to a depositor's drawing 90 or 100 per cent of his balance in a single check, because not all will do so at the same time.

The authoritative definition of the "diversity factor" does not deal explicitly with the point that is most important for rate-making, namely, the relation of the consumer's maximum or of his aggregate consumption to the station peak. This relation may be expressed by the ratio of his maximum demand to his demand at the time of the station peak — which it has recently been proposed to call the *individual* diversity factor.[1] Or it may be expressed by the ratio of the consumer's *average* demand to his demand at the station peak time — a conception analogous to that of the load factor, and a ratio which in strict logic ought to be understood in place of the consumer's individual load factor in most theorizing about the load factor in relation to rates,

[1] H B Gear, "The Application of the Diversity Factor," in the technical volume, proceedings of the National Electric Light Association, 1915 Convention, page 245.

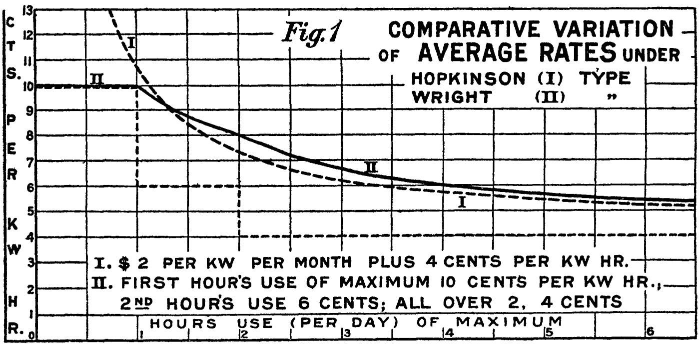
especially with reference to writings published before the general recognition of the importance of diversity.[1] It is, of course, the individual consumer's claim to consideration in respect to the character of his load curve that ought, if possible, to be recognized in the rate he receives. The objection to allowing for the diversity of a *class* of consumers by way of a class rate is that good and bad are lumped, and the average rate thus arrived at gives no incentive to the consumer to better the conditions of consumption with reference to the company's load factor, which betterment underlies the recognition of load factor and diversity factor in any form. But in the case of the small consumer the direct recognition of load characteristics is doubtless impracticable.

The character of the two important types of rate in which the load factor is explicit — as distinguished from being implied in the rate classification used — is shown by curves in Figure 1. True, there is another type of device, explicitly based on the load factor, by which the rate for current taken during the peak time of day is simply double that for other times, the result being obtained through a meter that registers twice as fast during the critical time. But this method of dealing with the problem is practically unused at present.

Figure 1 shows the difference between these two types — the Hopkinson type and the Wright type of rate. The former consists of two charges which are combined in computing the consumer's bill, one being so much per unit of demand (maximum kilowatt capacity required), and the other so much per kilowatt hour of energy actually consumed. It may be, for example, $30 per kilowatt per year plus 3 cents per kilowatt

[1] Which may conveniently be dated by the adoption of its definition by the American Institute of Electrical Engineers, June, 1911.

hour. In the figure the hypothetical charges used are $2 per kilowatt per month plus 4 cents per kilowatt hour. The Wright type consists of two or more successive prices per kilowatt hour, the extent of application of the higher rate for the first block of energy consumed depending upon assumed or determined demand (or active connected load) in relation to hours' use per month or per day of such demand, with a lower rate for



succeeding hours' use, there being in all commonly three successive charges per kilowatt hour, sometimes distinguished as primary, secondary and tertiary rates. For example, 12 cents for the first 30 hours' use of active connected load per month, 6 cents for the next 30 hours' use, and 4 cents for all over 60. If the active connected load is 1½ kilowatts, then the cost of 100 kilowatt hours a month will be 1½ × 30 = 45 kilowatt hours at 12 cents, or $5.40, another 45 at 6 cents, or $2.70, and the remaining 10 kilowatt hours at 4 cents, or 40 cents, in all, $8.50.

The advantage of the Hopkinson rate, as is indicated in the curves, is its continuous variation, conformably to the variation of cost. But the Wright type adapts itself better to the prejudice of the consumer who does

not want to pay a bill when he consumes no energy, and also to the situation when a legal maximum per kilowatt hour is prescribed. In practice the Hopkinson type seems to be preferred for large consumers, but the Wright type is the load-factor rate that is commonly applied to small consumers.

But, as has been implied in the foregoing, the difficulties of determining the load characteristics of the small consumer make a thoro-going application of load-factor principles impracticable. The Wright rate as applied depends mostly on makeshift estimates and classifications, instead of relating to actual maxima and actual diversity. Diversity, moreover, is coming to take care of most of the small lighting consumers' demand, so that there is less need of watching his individual maximum and of making him pay high for short hours' use.

For the large consumers, on the other hand, such metering as gives not only the maximum but the whole load curve is entirely practicable, and therefore the rate may deal with load characteristics directly and explicitly. It is scarcely necessary to say that for such consumers low rates granted on load-factor grounds should be based upon the properly determined load factor and diversity of the consumer. The Hopkinson type of rate is adapted to the requirements of this situation. But in relation to the kilowatt charge at least as much importance ought to be attached to the consumer's demand at the time of the system peak as to his individual maximum. This might be accomplished by averaging the former with the latter. Of course in still other cases a low one-charge rate per kilowatt hour may be granted for purely off-peak demand, provision being made to prevent current being taken during the one or two hours of the station peak.

Certain general conclusions or inferences from the foregoing discussion, partly implied, partly already stated, may be briefly set forth as follows.

It is not sufficient to rank a consumer, with reference to load-factor considerations, according to his hours' use of maximum demand merely. Only when his maximum coincides with that of the station is this procedure correct. His diversity may fully make up for a low-load factor; and this even tho his individual load factor has some small direct importance with reference to the necessary investment in service, meter, etc. An unvarying load is also very likely superior from an operating viewpoint. But the diversity ratio is at least equally important, and according to strict load-factor analysis, it is almost exclusively important in relation to fixed charges.

Another fundamental point in relation to the load factor is the great individual differences between consumers who may be, and usually are, lumped under the same class rate. Some averaging of conditions is inevitable in rate-making. But to give an individual consumer the benefit not of his own actual load factor and diversity ratio, but merely that of the average rank of the class with which he happens to be put, is open to fundamental objection. It is a merely static policy, giving no effective incentive to longer hours' use or to off-peak use. The bettering of the load factor of the company lowers cost, and the humblest contribution to the better situation ought, if practicable, to be given a full share of the resulting benefit in the form of a lower rate for a more intensive use of installation, especially off-peak use. For large consumers, at least, electrical rates should be definitely and explicitly dynamic. The Hopkinson type of rate — but with the diversity ratio emphasized as much as the load factor in determining

"demand" — offers the strongest incentive to diversification and intensification of use in a way to promote the improvement of the electrical company's load factor.

It is implied in what has been said of the relation between individual peaks and the station peak that load-factor analysis is not a matter of hard and fast allocation or separation of costs. If the station peak changes its position as to time of day, or if there is a plateau rather than a peak at the time of heaviest loading, it is obvious that the merely mathematical treatment of kilowatt or fixed-charge burden is not adapted to such a situation. But if the load-factor rate is considered a matter of commercial policy or a means to increasing the company's business in the direction desired, then the needed elasticity and adaptability is provided for and load-factor rates may be regarded as merely one very important species of differential rates.

II. Wholesale or Quantity Discounts

While the importance of the load factor in cost is peculiarly characteristic of electricity supply, yet, partly because it is not always a simple matter to determine the relation of the consumer's maximum demand to the system load factor, and partly for more general reasons, the most serious practical problem in constructing a fair rate schedule arises, not in connection with the load-factor aspect of rates, or not directly so, but instead in connection with the specially low rates granted to large consumers.

It is plausibly argued that the large consumers have better load factors and therefore should have lower rates. But we need attach little weight to such an argument on behalf of discounts based entirely on quantity. Classification by mere quantity taken is obviousl too

crude to fit load-factor conditions. For some conspicuous groups it does not fit at all, notably in the case of department stores and office buildings. Furthermore, if the due recognition of the load factor is what is purposed, it is entirely practicable to register the variations of the load of large consumers and give to each of them the full benefit of his load and diversity as such.

It should be added, perhaps, that because of the diversity of the different elements constituting the large consumer's kilowatt hour requirement, the computation and comparison of load factors would not of itself fully justify correspondingly low rates to him. The diversity in question would favor the company as much if each element represented a different consumer. Such large consumers usually combine both power and light. These two, tho often metered separately, are ordinarily billed together; yet the company is no better off because of the mere fact that they are billed together. Their simple combination will result in a higher load factor than holds for either separately. The situation is similar as regards the load factor of a landlord who combines his tenants' consumption with his own. Diversity is not increased by combined billing. The fact that the diversity influences intermediate load factors, as well as that of the electrical company, has no particular bearing on rates. At least there is no occasion to give to the large consumer more advantage from the diversity within his own consumption than an explicit load-factor rate would give.

The actual grounds for low rates to large consumers are not so much technical or strictly economic as commercial. Concessions are made chiefly in order to get business that is wanted. Naturally the management feels that the large consumers are the ones specially

worth getting. They are also the ones with special bargaining power. Under these circumstances they sometimes obtain, not merely low rates, but rates so low as to involve discrimination. The writer is not in position to say from his observation and study of actual rates and their results that the managers of electrical companies in this way often overreach themselves and do harm to their business, as well as injustice to the public. He must refer rather to the general tendency of human nature to take sides and to become aggressively partisan when involved in economic competition or in any other kind of fight. For the rest, observation of the quality of the analysis of costs offered on behalf of the central-stations indicates that much "increment cost" reasoning is born of a desire to defend policies and practices that are evidently discriminatory. The supposed "individualization" of cost — a term which is pertinent only when it refers to the individualization of separable cost — is as much beside the mark as is the other extreme view of those who want uniform rates per kilowatt hour.

Let us consider the two sides of the question of large quantity discounts for electrical supply.

The supply of low-tension electric energy from the regular distribution system is, on the face of the matter, peculiarly devoid of any reason for granting to the large consumer a better rate per kilowatt hour than to the small consumer. The kilowatt hours supplied are as absolutely homogeneous as applied science can make them. There are no differences between small and large packages, no true "bulk delivery," no differences in cost of handling, nothing analogous to the "car-load lot" of freight rates. It is not without significance that etymologically speaking there is no such thing as "wholesale" electric supply. The original idea of the

word " wholesale " was evidently, for example, that of selling cloth by the piece instead of by the yard, a specified number of yards being cut off in the latter case as wanted. But there is no such thing as a " piece " price for electricity, the supply being potentially continuous.

It is significant in this connection that, in graduating the rate to meet the expectations of large consumers, the electrical companies encounter a difficulty that does not occur with ordinary wholesale prices. If, for example, 7 cents per kilowatt hour is an appropriate rate for a consumer taking 1000 kilowatt hours or more a month, and 4½ cents per kilowatt hour for a consumer taking 10,000 kilowatt hours or more, the ordinary commercial practice would be to state the rate in that way; just as one rate is quoted per dozen, and a rate proportionately less per gross. But in such case there would be consumers taking somewhat less than 10,000 kilowatt hours who would pay somewhat more than those taking just that quantity or a little in excess of it; so that at a certain stage a consumer would have the incentive to use more current in order to reduce his bill. This situation can be met by a proviso to the effect that a consumer taking not more than 10,000 kilowatt hours shall pay not more than $450. Even this means that there is a free zone for the consumer just under 10,000 kilowatt hours, where he can use energy without increasing his bill. Hence the more general solution is to frame the schedule on the so-called " block " instead of the " step " principle. By this method the large consumer pays for an initial block at the same rate as the small consumer and for successive further blocks at decreasing rates, so that the average rate varies continuously with the size of the consumer. The difference between the " step " and

"block" methods [1] is illustrated by the curves of Figure 2. The nature of their construction calls for no detailed comment.

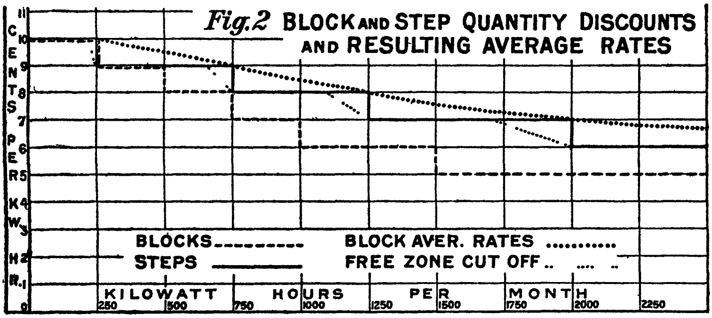


Fig. 2 BLOCK AND STEP QUANTITY DISCOUNTS AND RESULTING AVERAGE RATES

Hypothetical data of Figure 2 Rates per month per kilowatt hour.

Quantity	*Block Rate*	*Step Rate (by consumer size-classes)*	
Up to 250	10 cents	Less than 250	10 cents
251– 500	9 "	From 250 to 750	9 "
501– 750	8 "	" 750 " 1250	8 "
751–1000	7 "	" 1250 " 2000	7 "
1001–1500	6 "	" 2000 " 3000	6 "
Over 1500	5 "	More than 3000	5 "

It is true that the cost of metering and accounting, etc., is larger per kilowatt hour for the very small consumer. But this ceases to be an appreciable difference before the quantity discounts become marked and is not an actual factor in wholesale rates proper. Furthermore, it is often taken care of, and very properly, by a special feature of the rate, namely the consumer charge or the minimum charge, a matter which there is no room to discuss in the present paper.

Turn now to another phase of the situation. There is probably no great industry where the fixed investment in *distribution* plant is more important than in electricity supply. It is, therefore, economically necessary to develop business to the fullest possible extent in the

[1] The terminology is that of the Rate Research Committee of the National Electric Light Association. See Convention proceedings, 1912, vol. i, p. 199.

territory served. The large consumers are therefore needed. On the same ground the more complete occupation of the field afforded by the small consumers is desirable; yet this seems to be regarded in a different light.

It is here that we find the principal reason why large consumers are offered specially low rates — the strong competition between isolated plants and central stations. The large consumer is able to supply himself by operating his own electric plant. This is not so uneconomical as it might seem in view of the general advantages of large-scale production. The private plant requires no investment for a transmission and distribution system. The steam end of the plant is presumably needed in any case for heating, and the heating may be done largely with low-pressure exhaust steam at inappreciable cost — if the operation of the plant be considered chargeable to the electrical use, or *vice versa* — always provided that the heat and electric energy are largely needed at about the same time. As to the importance of the isolated plants, it suffices to point out that if the central stations could put most of them out of business, the former would double their output.

A landlord of a large apartment house or office building thus has the option of supplying his own electricity or buying it, and he is therefore in position to bargain for a very low rate. This has lead in New York City to so-called "merchandizing" contracts, under which a landlord might buy from the electrical company at approximately 5 cents a kilowatt hour, and then sell to his tenants at 10 cents or a little less; the electrical company furnishing and reading all the meters and supplying the lamps, just as it would do if it dealt with the tenant individually and received for its services 10

cents per kilowatt hour instead of half as much. It is scarcely necessary to say that the Public Service Commission has disapproved of this practice and compelled some modifications of it. A detail that still stands is the counting of tenants' consumption towards the minimum annual consumption that entitles the landlord to the wholesale rate.

Under the circumstances mentioned, it is evident that a pure quantity discount amounting, even after deduction of something from the maximum rate to take care of consumer cost, to two-thirds and more of the retail rate, appears to be open to attack as discriminatory. But the importance of full utilization of the distribution system cannot be questioned. If the large consumer must be allowed to make only a minimum contribution towards the carrying charges on the distribution system in order that he be kept for the central station, it is good business from a social point of view as well as pecuniarily for him to be supplied under a rate as low as this situation implies.

Nevertheless, from an economic viewpoint, it is *density* of consumption that the central station needs; not large consumers as such, still less composite or "merchandizing" customers. If, in order to maintain density of consumption, it is necessary to grant low rates to loft and office buildings and apartment houses, it would seem best to make the density factor explicit in the rate schedule; that is, to grant discounts from the maximum rate on the basis of kilowatt hours consumed per month or year per foot or block front, or according to some other convenient and practicable measure of density. Such discounts should not depend upon whether the consumers within a given block are billed separately or through the landlord; altho, for reasons of administrative cost, it could hardly be

expected that the discounts would be offered to the smallest consumers as well as to medium and large consumers. So far as the writer knows this solution of the problem is original with him and untried, and it is made merely as a suggestion, subject to qualifications and modifications through experience.

There can be no objection in principle to a differential distribution of the burden of fixed charges in order that the central-station company may keep or get the business that would otherwise go to isolated plants. By differentiation is meant the non-uniform, or other than pro-rated, distribution of fixed charges and other joint costs. Within limits, the policy is defensible on general economic grounds, in relation both to the load-factor situation and the density-factor situation of the electrical-supply company. But the electrical companies doubtless need to be restrained from over-stepping bounds in their pursuit of traffic, and from passing beyond differentiation into discrimination.

III. Conclusions

It is a common assumption that rates can and should be based upon cost, in a sense which supposes the separate cost of at least every particular class of service, if not that of every individual consumer, can be ascertained. A pointed way of putting this claim is to allege that an equal profit should be taken from each class of consumers per unit of service performed. Of course if the "profit" can be thus definitely and arithmetically determined, that to which it is supposed to be added to make the resulting definite charge, namely the "cost," must be already definitely determined or determinable for the separate consumer or class of consumers.

It is true that load-factor analysis has been commonly put forward as a definite solution of the problem of the distribution of fixed charges among consumers, according to the responsibility of each consumer or class of consumers for these charges. We need not quarrel with the earlier proponents of the load factor if they claimed too much for it, especially since the importance of the diversity factor has only lately become clear. The argument was (and largely is) that costs, including return on capital, could be divided into two classes, running expenses and fixed or general charges, and that the fixed charges should be apportioned among consumers according to their maximum demands (kilowatt requirements) and the running costs apportioned according to kilowatt hours consumed. This directly leads to the Hopkinson or two-charge type of rate.

A preference for some such type of rate, where the scale of the consumer's requirements makes it practicable, does not imply, however, that the corresponding cost analysis accomplishes the separation of total costs in a way to make it possible to charge each consumer or class of consumers strictly according to the burden imposed on the company. If the maximum load of the company determines its necessary fixed charges, yet because of the diversity factor, the sum of the maxima of individual consumers is greater than that. Of course it is possible to scale down all these maxima in the ratio of the system diversity factor. But is an individual kilowatt maximum that occurs at midnight equally a burden upon the company with one of the same number of kilowatts that occurs at the hours and days of the system peak, say 5.30 P.M. during December.

An obvious alternative is to consider only the composition of the station peak in distributing fixed charges,

and put upon each consumer a demand charge proportioned to his kilowatt requirement at the time of the station peak. But will the electrical company be willing to exempt from all demand charges consumers who take no current at the peak time ? Off-peak rates, it is true, are known, but the writer is not aware of any plan by which such consumers are systematically exempted from contributing something towards meeting the company's fixed charges. But if consumers entirely off the peak are compelled to pay anything for the use of the plant, the supposed principle according to which total costs are not merely apportioned by classes of consumers, but actually separated, is abandoned. And if the scheme in question were tried, what would happen where conditions gradually changed so that the 5 P.M. load became the peak in place of the 6 P.M. load ? A consumer who closed his place of business at 5.30 P.M. would suddenly pass from the class of those who have no demand charge to pay, to the class of those who pay a heavy demand charge in addition to a kilowatt-hour charge. Of course the peak period could be more broadly defined. But all this is mere speculation. Of the numerous attempts of engineers and accountants to distribute fixed charges with the finality of separable costs, none will stand analysis. But where the rate schedule has developed in conformity with economic requirements, consumers with undesirable load characteristics (large consumers at least) pay more per kilowatt hour, and those with better load characteristics, especially with long hours' use, pay less per kilowatt hour. In other words, the load factor is a *guide* in the differential distribution of fixed charges. A long-hour user is charged less per kilowatt hour partly because of his less cost, but partly also, under an intelligent rate schedule, in order to encourage a more intensive use of

installations, both on his part and on the part of others.

This is merely what all legitimate price differentiation undertakes to do, namely to improve load and capacity factors. The reasons for charging a different price for kilowatt hours taken at different times is, in some respects, clearer than the reasons why a railroad charges a different price for carrying a ton of coal and a ton of wheat the same distance; but in other respects the electrical case is less clear and less convincing. If we start with the principle that the same quantity of service ought to cost the same price to all comers and at all times, then, since modern electrical instruments determine accurately both the quality and the quantity of the kilowatt hour, we find the kilowatt hours supplied by a given company are more homogeneous than two different tons of coal supplied from the same mine, not to speak of differences between coal and wheat. As to the difference in the time of the demand, that is a question of degree of utilization of plant, and therein similar to the question of getting additional freight. But the practical problem of full utilization is always present with an electrical company; while exceptions and qualifications may be necessary in the case of a railway.

To generalize from the foregoing: there are certain elements in cost that are fixed by the necessary extent of the plant, and, for the rest, are proportioned to time, not to the use made of the plant. All the cost of carrying the investment, perhaps most of depreciation, a good deal of general expenses, and a good deal of repairs, vary in proportion to time rather than to use. If the units of use for a given extent of plant are few, the burden of such costs per use unit is large; if the units of use are many, the unit cost is much less. If

fuller utilization can be brought about by differential prices, total unit cost is lessened; and then the policy of differentiation is economically justifiable. Since costs that vary with time are a permanent factor in the economic situation — a factor, as experience indicates, of increasing importance — differential rates must be recognized as permanent. Of course the policy of differentiation is often carried too far and becomes discrimination. But discrimination can be more effectively dealt with if we recognize fully and fairly the economic, and that includes the social, soundness of differentiation, that is, the non-uniform distribution of the fixed-charge element in cost, as such.

While the importance of the load factor constitutes the great peculiarity of the electrical rate situation, quantity discounts constitute the most troublesome practical problem. They, also, may be differential or discriminatory in character. Indeed it is in this form, rather than in that of load-factor rates, that differentiation chiefly manifests itself in electrical rate schedules. Quantity taken is perhaps more important than load characteristics as the reason for class rates, even where the latter are ostensibly based on load-factor grounds.

In this aspect electrical rates are chiefly of interest as showing the differential character of wholesale rates, which are ordinarily supposed to be based upon identifiable differences in costs. It happens that the latter sort of ground for wholesale rates is notably unimportant for the low-tension service of electrical supply companies, while the grounds for differentiation, or the non-uniform distribution of the fixed charges attributable to the distribution system, are especially important.

In both the respects discussed in this paper, therefore, electrical rates ought to be of great interest to

economists. The subject is, indeed, or should be, of interest to them according as differential rates are of general importance rather than merely according to their bearing on electric supply. To the general question attention will be given in a paper to follow.

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